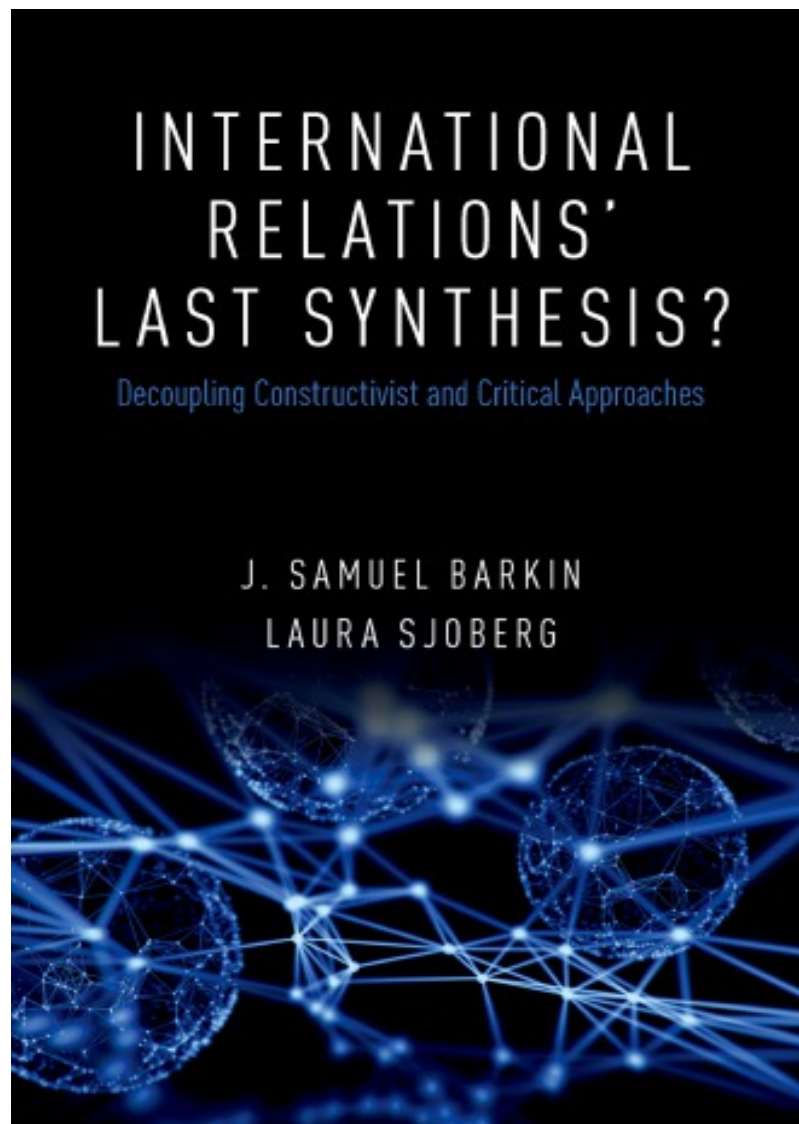


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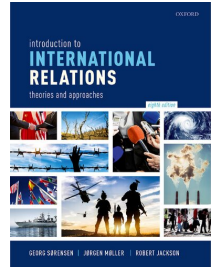


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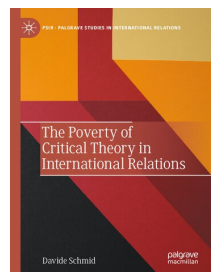
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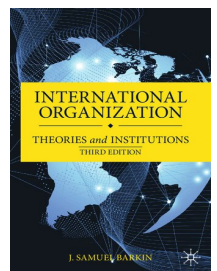
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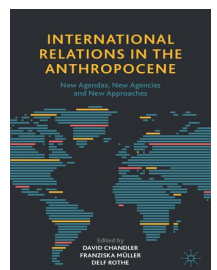
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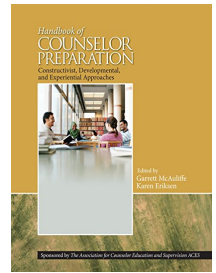
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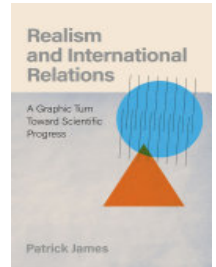
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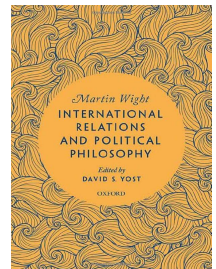
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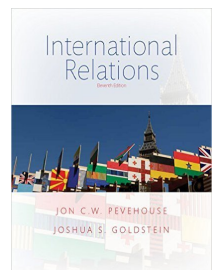
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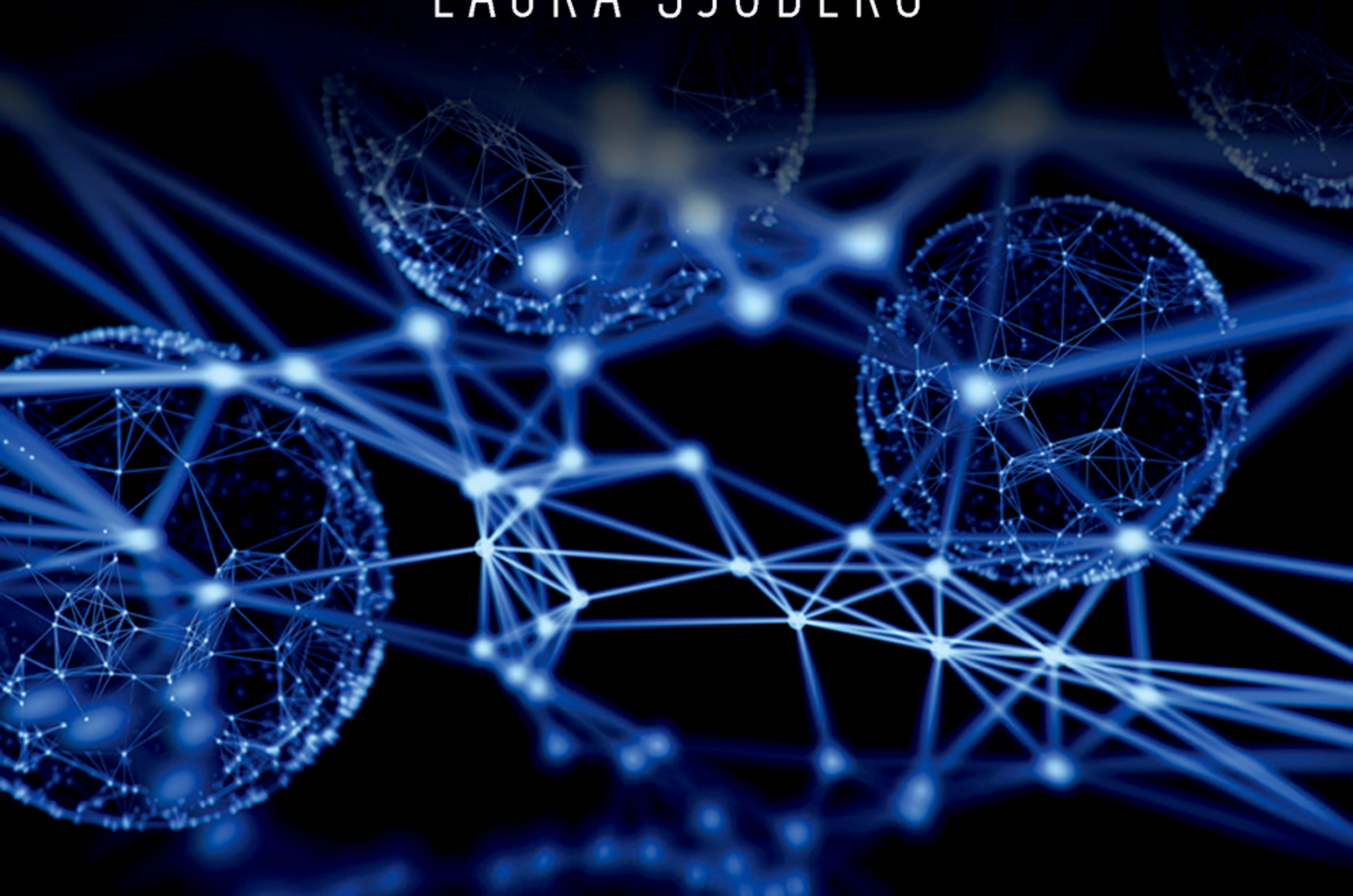
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INTERNATIONAL RELATIONS' LAST SYNTHESIS?

Decoupling Constructivist and Critical Approaches

J. SAMUEL BARKIN
LAURA SJOBERG



International Relations' Last Synthesis?

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*Decoupling Constructivist
and Critical Approaches*

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and

Laura Sjoberg

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Introduction

In 2014, Martin Weber argued that constructivisms' separation from critical theoretical approaches to the study of global politics was both intellectually incorrect and theoretically counterproductive.¹ Weber explained that "constructivism's rapid consolidation as a research program" has "shifted" International Relations (IR) "under constructivist influence," bringing with it methodological and theoretical challenges.² Weber, however, does not approve of this influence, given constructivists' "continuing penchant for explanatory social science" and "project of distancing such consolidations" from critical theoretical approaches.³ Unhappy with what he calls "mainstream constructivism," Weber critiques "the way in which . . . [it] engages with norms," which he characterizes as an "essentially behavioral" account. He suggests that distinguishing constructivisms from critical theoretical approaches in IR can "have negative repercussions for any attempt at integrating concerns with the role of norms appropriately into the broader social theoretic project aimed at analyzing political orders and change."⁴

Weber's argument that constructivisms should adopt a critical theoretical perspective, or step aside completely, *seems* to fly in the face of disciplinary norms. After all, just a year earlier the editors of the *European Journal of International Relations* suggested that there has been a strong decline in macrotheoretical IR work writ large, and that the macrotheoretical interventions that do exist rarely if ever engage in passionate critique of one theoretical position from another.⁵ Dunne, Hansen, and Wight described the evolution of a "theoretical peace" such that IR inquiry has "settled into a period . . . with the dominant logic now that of considering the prospects for various forms of pluralism."⁶ Suggesting that "all academic disciplines

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undergo periods of stasis and change,” they propose that the current period of IR theorizing is one of stasis, were “much work in IR has not risen to the level of meta-level theory, neither has it generated passionate debates.”⁷

It may well be that Weber’s passionate critique of “mainstream constructivism” is the exception and not the norm in terms of the presence of interparadigmatic debate in the discipline, as well as in terms of the publication of purely macrotheoretical arguments.⁸ But we argue that it is also outside the norm of disciplinary practice in another way. Wight argues that constructivisms and critical approaches to the study of global politics are both easily distinguishable and make different wagers in terms of norms and politics.⁹ Wight accuses constructivisms of “avoiding normative theory,” with “a prior commitment to social-scientific objectivity,” avoiding “strong normative commitments” and “relativism.”¹⁰ Returning to the rationalist-reflectivist separation in Robert Keohane’s 1988 presidential address to the International Studies Association, Weber accuses constructivists of inhabiting the via media to the theoretical and political detriment of the field. He argues that constructivisms and critical approaches *are separate* and should not be—that constructivists should adopt the orientations of critical theorizing.¹¹

We see this article as an anomaly not only because it breaks what Dunne, Hansen, and Wight call the “theoretical peace” but also because our reading of the sociological relationship between constructivisms and critical approaches to theorizing global politics in disciplinary IR suggests that Weber’s interpretation of the “problem” with the relationship between the two is both empirically and normatively incorrect. Weber reads some mainstream constructivists’ attempts to distance their work from critical theorizing as dominant in the field.¹² We suggest, instead, that narratives identifying a critical aspect to constructivism and a constructivist aspect to critical theory—perhaps in the name of a theoretical peace, perhaps not—are so dominant in the field, at least in the United States, that they have reached the status of being relatively unquestioned.¹³ Unlike Weber, who would suggest that it is a moral imperative for constructivisms to adopt the normative orientations of critical approaches, we argue that the fusing of constructivisms and critical approaches to global politics is on balance harmful, intellectually, politically, and in terms of disciplinary sociology.

Here, then, we arrive at the key controversy that this book looks to address: where do critical theory and constructivism fit into IR theory, and what is their relationship with each other? What does that relationship say about the existence (or lack) of a “theoretical peace” and the pros or cons of such a stasis? Does evaluating more closely the relationship between constructivist and critical approaches to IR provide clues about where IR

theorizing is, and where it might be going? Does such an evaluation provide any clues about Weber's burning question of where IR theorizing *should* be headed? Dunne, Hansen, and Wight find a middle ground on the question of grand theory in IR: "we do not seek to align ourselves with a view that celebrates the 'theoretical peace' and neither do we want to return to a paradigmatic 'war of all against all.'" ¹⁴ Rather than "align" with either extreme, they close "with the observation that disciplinary turning points' and 'great debates' are seen more clearly when the moment has passed" and suggest that history will tell us about this period in IR theorizing. ¹⁵

We suggest that it is important not to wait for history on this question, and that the answers to some of the pressing questions about the state, direction, and possible future directions of IR theorizing are indeed right in front of us. We argue that the "theoretical peace," the "end of IR," "analytic eclecticism," and other code words for an analytically fuzzy understanding of pluralism are, at their base, *sociological* rather than *theoretical*. They represent theoretical synthezation inspired by many forces in the field of IR, *but not* a clear understanding of the intellectual rationale for pluralistic approaches or synthetic understandings. ¹⁶ We suggest that the "theoretical" (and methodological) peace is manufactured.

In this book, we take on one of the most prominent products of this manufactured pluralism, tolerance, and similarity: the relationship between constructivisms and critical approaches. Whether as a part of an explicit or implicit "theoretical peace" or not, we suggest that work both inside and outside of constructivist and critical approaches to global politics portrays the two as being necessarily compatible or as existing on some unidimensional spectrum of radicalness, which spectrum is variously political, ontological, or epistemological. We call this portrayal, for reasons that will become clear in the next few pages, the critical-constructivist synthesis. We argue that the synthesis has become a common, permeating feature *both* of characterizations of disciplinary organization, especially in the United States, and of *substantive* descriptions of how the theoretical approaches do, or in Weber's case should, work. Though it has not been named as such in the past, we argue that the constructivist-critical theory synthesis has many advocates in the field and even more implicit adherents.

We also argue that the constructivist-critical theory synthesis is a *bad* idea—that it does not stand up to scrutiny of its substantive basis, its sociological impacts, or its politics. We contend that the sociology of the field, rather than any intellectual justification, constituted this synthesis and continues to make adherence to it professionally, if not intellectually, profitable. We suggest that this synthesis did not, and indeed could not, develop out of the content inherent to either approach—because

there is no commonality on which to build a synthesis. In addition to this synthesis not standing up to close examination, we argue that it is dangerous; it circumscribes what is considered legitimate scholarship in the discipline, and serves to exclude rather than to illuminate theory in the field. We argue that both constructivisms and critical theories should be thought of as tools for the study of global politics, rather than paradigmatic elements of IR theory. We argue that they should be thought of as *different* tools that *can* but sometimes *should not* be deployed for common analytical causes. We contend that the failure to separate constructivisms and critical approaches contributes to the stasis that Dunne, Hansen, and Wight identify in disciplinary IR.¹⁷

UNCOVERING THE NEW STASIS

This is why the juxtaposition of Weber's grand theoretical critique and advocacy of a constructivist-critical theory synthesis against Dunne, Hansen, and Wight's argument about the decline of those sorts of arguments serves as a good entry point to the discussion of the constructivist-critical theory synthesis. Dunne, Hansen, and Wight's argument is the introduction to a special issue of the *European Journal of International Relations* addressing the status of IR theory, provocatively titled "The End of International Relations Theory?"¹⁸ The authors use the question of whether IR (and IR theory) is at an end in a variety of different ways across the text of the article, but we are most interested in the discussions of if, and how, grand theorizing remains a part of inquiry about global politics in disciplinary IR.

Dunne, Hansen, and Wight note (and we agree) that there has been a decline in macro-theoretical clash among theorists and researchers of global politics. They introduce this decline with reference to disciplinary history: "it is clear that the intense theoretical debates that followed the publication of Kenneth Waltz's (1979) *Theory of International Politics* and which led to the 'third debate' (Lapid, 1989), or the 'fourth debate' if one follows Ole Weaver in including the inter-paradigm debate (Weaver, 1996), have now subsided and that the discipline has moved into what might be described as a period of 'theory testing'. The paradigm wars, if that is the correct term, are now over."¹⁹ We believe that Dunne, Hansen, and Wight are right to remember times when the stakes in macro-theoretical debates in IR were different, and when the clash between theoretical approaches was sharper. Still, that clash has not been consistent throughout the history of theorizing IR—it has waxed and waned with changes in the world of global politics and changes in disciplinary sociology. We agree with Dunne,

Hansen, and Wight that there is not *currently* a paradigm war, or raging grand theoretical debate in the study of global politics.

But this is not the first time that IR theorizing has featured a lack of grand theoretical debate, and we argue that a broader look at the inherited narratives of disciplinary IR is revealing about the current state of the field. Particularly, one of the times when the “paradigm wars” were in full swing was the 1980s, where there was a core theoretical debate between neorealism and neoliberalism. The debate between the two in *Neorealism and Its Critics*,²⁰ Waltz’s *Theory of International Politics*,²¹ and Keohane’s *After Hegemony*,²² were once characterized as a major *clash* in the study of global politics, bringing up key differences in orientation—particularly the debate about the possibility of cooperation between states in an anarchic international arena.²³ At the same time, the neorealist and neoliberal approaches to understanding how global politics works shares many common ontological and methodological understandings. These commonalities *increased* throughout the course of theoretical arguments across the paradigms, as neoliberals subscribed to neorealists’ postulations about the anarchical nature of the international system and states’ propensities to seek relative gains over absolute gains.²⁴

The increasing agreement between these approaches and the *narrowing* of the substance on which they clashed led Ole Waever to suggest, in the 1990s, that the field was no longer in a place of grand theoretical clash but was instead in a place that Dunne, Hansen, and Wight might call stasis, where the major theoretical approaches came to agree more than they disagreed, and formed what Waever called the neo-neo synthesis.²⁵

Inside the synthesis were neorealism and neoliberalism, which agree substantially on some of their major tenets regarding how global politics works and which appeared at the time to have a chokehold on grand theoretical debate about global politics, restricting the debate to their own minor differences. An *outside* of the synthesis quickly developed, unwilling to accept the narrowness of the neo-neo synthesis or its tendencies to set the terms of scholarly debate. Various forms of radical IR, with little else in common, stood outside the synthesis and argued against it. The forms of critique ranged from the ontological to the methodological to the political, and these critiques of the neo-neo synthesis were often not mutually compatible. This category of paradigmatic other was often generically labeled “Marxist” during the Cold War, but this label was slowly replaced by “constructivism” or “critical approaches” after the demise of the Soviet Union. The critical-constructivist synthesis, we argue, is the direct descendant of this category of radical paradigmatic other.

The late 1980s, then, is told as a time when stasis was replaced by debate—the neo-neo synthesis giving way to what IR theorists have alternatively called the “third” or “fourth” debate, between the neo-neo synthesis and its (epistemological, ontological, or methodological) constitutive other(s). The existence of this “debate” (and the very telling of the history of disciplinary IR through stories of two-sided debates) at once defines the terms of the clash that reinvigorated grand theorizing *and* groups the “other side.” Many of IR’s substantive wagers are up for debate in this framing of the discipline: grand theoretic questions, like what ontology and what epistemology are best for the study of global politics, are up for discussion in a way they were not during the neo-neo synthesis.

At the same time, the substantive wager that is (under the radar) *not* up for debate is the need to explain the theoretical landscape of IR in terms of coherent, dichotomous clash. The end-of-IR-theory discussion looks back to the 1980s as a time of disciplinary coherence, when there was a generally accepted disciplinary core that provided the touchstone for discussions of grand theory, whether one was positively inclined toward that core or not. This discussion then looks at the following debate as a clash on which there were two possible positions: *for* the neo-neo synthesis and *against* it. Positions *for* the synthesis were *within* it; positions *against* the neo-neo synthesis came to be synthesized themselves in oversimple, comforting stories of a discipline that was coherent even in its disagreements.

Various entrants into these discussions have argued that IR theorizing is declining, because that core has lost its centrality to the discipline, or that it continues to go strong, because other cores are replacing it. They argue that decline is bad and should be reversed, or that it is good and the resulting theoretical eclecticism should be celebrated.²⁶ It is against this background, of a paradigmatic view of theory and a nostalgia for a more coherent discipline, that critical theories and constructivisms are pressured into a synthesis. If IR is a discipline of grand theoretical debates, it follows that IR scholars will manufacture grand paradigmatic syntheses about which to debate—narratives about disciplinary coherence demand it, and those are the only part of disciplinary IR that have been *inflexible* across debates, periods of change, and periods of stasis.²⁷

It was the inflexible search for coherence, we argue, that constituted the neo-neo synthesis itself, that inspires debates like the “end of IR” discussion,²⁸ and that encourages scholars to espouse an analytic eclecticism that is substantively problematic.²⁹ We suggest that the need for coherence *combined* with the disciplinary power politics of the mainstream have created, paired with (and simultaneously pared against) the neo(realist)-neo(liberal) synthesis in IR, a new theory synthesis *among the critics of the*

neo-neo synthesis. We identify this as the constructivist–critical theory synthesis, for ease of labeling, though we see it involving many different sorts of constructivisms and many varieties of critical theory. Across this text we will refer to it alternatively as the constructivist–critical theory synthesis, as an imaginary disciplinary “left,” and as what we argue should be the discipline’s last synthesis.

INTERNATIONAL RELATIONS’ LAST SYNTHESIS

In this book, our identification and recognition of the constructivist–critical theory synthesis is not simply an exercise in field mapping and theory labeling. Instead, we make a series of arguments that the constructivist–critical theory synthesis has become inherited wisdom in a deeply problematic way that obscures theoretical richness and impedes clarity in research about global politics. To make that argument, we start by thinking about Ole Waever’s critique of the neo-neo synthesis in the early 1990s.

Waever’s critique of the neo-neo synthesis was multifaceted. Both in the chapter where he criticized the synthesis and elsewhere, Waever made it clear that he fell on neither “side” of the dichotomous debate: that his theoretical orientation was outside neorealism and neoliberalism.³⁰ But he suggested that his falling outside boundaries of the neo-neo synthesis was a problem that was *orthogonal* to the problem of the synthesis itself, which created a chokehold not only on its constitutive others but also on the theories *within* the synthesis. Waever argued that the disciplinary IR of the 1980s had come to be dominated not just by neorealism *and* neoliberalism, but by a combination of the two that made the synthesis between them less than the sum of its parts.³¹ He pointed out that the tightening of disciplinary power around these *two* approaches had the effect not only of excluding approaches that fell outside them but also of decreasing the intellectual viability of each individual approach.³² He explained that both neorealism and neoliberalism, in the process of entering the *political* synthesis for disciplinary power, “underwent a self-limiting redefinition towards an anti-metaphysical theoretical minimalism.”³³ In this redefinition, each “side” of what had once been an opposition stripped out of its theoretical positions the elements that would be incommensurable, in order to make feasible a synthesis. The result was that in the neo-neo synthesis, “realism is no longer an ethico-philosophical position” and liberalism “moved away from being a general interpretation of the nature of international relations . . . and concentrated instead on asking a few precise questions.”³⁴

With Waever, we think that the theories in the neo-neo synthesis were less than the sum of their parts *because* of the sociological and political choice to engage in exercises of synthesization.³⁵ The understanding that these theories *should* agree narrows potential fields of inquiry significantly and destroys some of the richness of each individual theoretical approach. Instead, we see both normative and intellectual value in *disagreement* and *distinction*—where (with Hayward Alker and Tom Biersteker) “it is the sharing, the interpretation, and the principled opposition of these often antagonistic approaches . . . that truly constitute the global inter-discipline of International Relations.”³⁶ Alker argues for a “controversy-based path” to the production of scholarship.³⁷ Eschewing the sensed obligation that theories *should* agree allows for the dropping of the pretense that they *do* agree.

If the neo-neo synthesis was destructive to grand theorizing, it was because the generally agreed-on framework created a sense of comfort about (and discouraged discussion of) the “big questions” of what is happening in global politics. If that destruction of grand theory ended—if IR got over the “wall” of neo-neo synthesis—it was because some theorists (particularly constructivists and critical theorists, although not necessarily for reasons of common epistemological assumptions) started paying attention to those “big questions” again, and critiquing inherited assumptions that those questions had been solved. In other words, the synthesis itself narrowed and silenced inquiry about big theoretical questions as it looked for disciplinary security or hegemony, and the process of *deconstructing* that synthesis from the outside both opened up previously closed areas of inquiry *and* allowed for the development of stronger and more nuanced approaches, even to the approaches that had once been synthesized.³⁸

If the neo-neo synthesis no longer has a chokehold on either adherents to realist/liberal approaches or the discipline as a whole, we argue that the problem of synthesis itself has not gone away. Instead, a new, less visible but equally influential synthesis has been positioned as an imaginary disciplinary “left” between constructivist and critical approaches. As we discussed earlier, constructivist and critical approaches, originally the constitutive other to the neo-neo synthesis, appear, in some sense, to have “won” the positivist/postpositivist debate in IR, as many scholars self-identify as constructivist,³⁹ and many scholars who do not self-identify as constructivist or critical acknowledge the importance of including those approaches on the map of the ways the discipline works.⁴⁰

We argue, however, that this “victory” is partial and comes at the high cost of the institutionalization of a constructivist–critical theory synthesis. Particularly, we see that the constructivist–critical theory synthesis carries

with it many of the same costs as did the stasis that preceded it thirty years ago. Not only is the combination of the two divergent approaches intellectually problematic, it has negative effects on disciplinary sociology, disciplinary politics, and ultimately the project of theorizing itself. Throughout this text, we focus on three major costs of what we argue should become IR's last theoretical synthesis.

The first major cost is that the constructivist–critical theory synthesis misunderstands, mistakes, or perverts both constructivism and critical theory. In other words, the intellectual wagers of the constructivist–critical theory synthesis are incorrect. Much of this book is devoted to making the case that the logic of the synthesis, despite its popularity, is false; there is no necessary paradigmatic commonality across constructivisms and critical approaches. We look to disentangle constructivisms and critical theorizing, paying attention not only to their (potential) commonalities but also to each theory's ontologies, epistemologies, and politics and the ways they differ substantively. In so doing, we hope to clear up arguments about constructivist politics and critical methodology that we see as muddling twenty-first century IR theory. A discourse of synthesis, of a paradigmatic or radical theoretical other, leads scholars to both misunderstand and underestimate what both approaches can do.

We argue, moreover, that a default or intentional synthesis between constructivisms and critical approaches has more costs than the problems with its intellectual wagers. The second major cost of the constructivist–critical theory synthesis is that it is exclusionary. Scholarship outside the mainstream of the discipline that does not fit into the prescribed boundaries of the synthesis, that does not fit into the terms of the supposedly radical other, can find no place on the maps of IR scholarship. If the constructivist–critical theory synthesis is the acceptable/accepted “other” to the neo-neo synthesis, work outside either necessarily falls outside the discipline as told by the dominant narrative, and the telling of the discipline often constitutes the availability of space and tolerance for particular approaches. Synthetic debates can thereby easily become about boundary-setting, about what scholarship to exclude, rather than about what individual exercises in IR scholarship can teach us about global politics. In other words, the constructivist–critical theory synthesis *tells out of possibility* other approaches that might defy easy categorization or oversimplifies them into categories where they may not fit; deconstructing the synthesis would allow attention to the nuances of a wider variety of approaches.

The third cost of the constructivist–critical theory synthesis is that it reinforces a disciplinary language of paradigms, of thinking about

constructivism or critical theory (or realism or liberalism for that matter) as comprehensive sets of ontological, epistemological, methodological, and political commitments that can and indeed must be taken together as a set. Returning briefly to the “end of IR,” debate, we argue against *both* a “theoretical peace” and “paradigm wars,” but *not* because we are going to look either to history or another grand narrative. Instead, we suggest that deconstructing this false synthesis (and others like it) allows us to see what theories really can do, what intellectual wagers they make, and what their possibilities and limits are in terms of the analysis of global politics. The mistake that both the “paradigm wars” and the “theoretical peace” make is the one insistence we see as constant across tellings of the disciplinary history of IR: the search for the combination of coherence and totality. What Dunne, Hansen, and Wight see as an “uneasy truce” in favor of pluralism, we see as a way of framing disagreement and necessary dissonance coherently, thus eliding the messiness of that dissonance.⁴¹ The new “pluralist” coherent narrative downplays the importance of theoretical difference⁴²—or even theory itself.⁴³ When theoretical approaches are invoked, then, they are invoked as a background condition for a particular substantive (or, in Weber’s case, normative) argument.⁴⁴ This common invocation of theory, along with the lingering understanding of theoretical approaches to global politics as coherent paradigms, suggests that each theoretical approach to global politics both *has* and *shares* a full set of tenets about how the world works (ontology), how to know how the world works (epistemology), procedures for discovering how the world works (methodology), tools for uncovering that information (methods), and normative orientations toward that information (politics). Paradigms are assumed to be both internally coherent and comprehensive—an assumption that has been taken for granted along all of these axes, even in its contestation, since the importation of Imre Lakatos’s philosophy of science into inquiry in disciplinary IR.⁴⁵

This assertion is, in our view, an overestimation of the potential of paradigms, which leads to totalizing overstatements of their possible contributions. The words “neorealism” and “neoliberalism” in the neo-neo synthesis were used as shorthand stand-ins to describe worldviews understood to be both comprehensive and fully coherent. We suggest that the terms “constructivism” and “critical theory,” along with their synthesis, have come to serve a similar function, where each refers to an undefined but assumed full set of tenets about global politics, from ontology to methods. But neither critical theory nor constructivism (like realism or liberalism) provides the intellectual basis for such a full set of commitments. Constructivism, as we argue in chapters 3 and 4, provides

a basis for ontological and methodological but not epistemological or political commitments. Critical theory, as we argue in chapters 5 and 6, provides a basis for political but not ontological, epistemological, or methodological commitments. Furthermore, broad ranges of varieties of both constructivisms and critical theories exist, and trying to fit them into paradigms, let alone into a synthesis, does violence to this variety. The “paradigm wars,” then, were not only problematic for their dichotomous understandings of the factors that might possibly account for what happens in global politics. They were problematic as well for their totalizing *inclusion* of approaches, not only in the synthesis between paradigms but in the paradigm itself, inasmuch as the *idea* of a coherent paradigm in disciplinary IR overpromises intellectual wagers, and therefore necessarily underdelivers imagined coherence, dichotomous possibilities, and manufactured commonalities.

REJECTING THE CURRENT STASIS OF IR’S THEORY

Instead of wondering whether IR theory is over, or whether the new “trend” that Dunne, Hansen, and Wight call “theory-testing” has taken irrevocable hold,⁴⁶ we suggest that IR’s current stasis strongly resembles the neo-neo synthesis. We argue that IR theory is currently stuck in a rut much like the neo-neo synthesis of the 1980s, built from a similarly limiting alliance of the neo-neo synthesis’ opponents. We argue that the constructivist-critical theory synthesis, like the “wall” of the neo-neo synthesis, is (intentionally or not) a political agreement that distracts attention from the “big questions” about global politics that theorizing in IR could and should address. The underspecification and overreached application of genericized constructivisms and critical theorizing in IR make efforts to address these kinds of questions more fraught and less effective. We contend that these implications make it necessary to critically reevaluate figurations of constructivist/critical IR to correct for this failure of clarity.

This book project is at once interested in assessing the theoretical map of the discipline of IR and in using insights about that theoretical map to further both conceptual and empirical understandings of how global politics works. In the wake of the rising popularity of arguments about the “end of IR theory,”⁴⁷ this book sees a world in which IR theorizing is alive and well and is a key part of both disciplinary analysis and disciplinary self-identification.⁴⁸ While we see the continued importance of theory even in scholars’ disavowal of it, we recognize, with those who declare theory’s death in the discipline, that *something has changed* in the structure

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Exploring the Variety of Random Documents with Different Content

A rainbow is seen when the sun shines through the drops of water as they fall through the air.

How do the drops of water help to make a rainbow?

The drops of water act like little prisms, and separate the rays of light passing through them into the colors of the rainbow.

What two things, then, are needed to make a rainbow?

A shower of water, and a bright sunshine.

25

In what part of the sky does the rainbow appear?

In the part opposite to that in which the sun is, at the time of the shower.

How does the rainbow appear?

It appears like a great arch, spanning the sky, and its splendid bright colors are very beautiful.

What may we remember in reference to the rainbow?

We may remember that God set his "bow" in the cloud, as a token that the world should no more be destroyed by a flood of waters.

Where else may we see a variety of colors?

In the soap-bubble.

Why are these colors constantly changing?

Because the walls of the bubble are constantly growing thinner, and different colors are, therefore, reflected from them.

Why do the walls of the soap-bubble grow thinner?

Because the water runs to the bottom of the bubble until its top becomes so thin as to burst.

Can we tell the color of any object by touching it?

No; we must see it in order to tell its color.

How do we know this?

If there are two coats, one blue and the other black, we cannot tell which is the blue one or which is the black one, by feeling them.

What is necessary in order to see the colors?

Light is necessary; because all colors come from the rays of light.

Can we see the different colors in the ray itself?

We cannot; because God has so blended them together that they cannot be seen by us.

26

When most of the rays of light pass through a substance, what is said of it?

The substance is said to be *transparent*.

Name some transparent substances.

Glass, ice, diamonds, air, and clear water.

When only a few rays of light pass through a substance, what is said of it?

The substance is said to be *translucent*.

Name some translucent substances.

Flint, isinglass, scraped-horn, and china-ware.

When no rays of light pass through a substance, what is said of it?

The substance is said to be *opaque*.

Name some opaque substances.

Wood, iron, coal, and granite.

Can we see through a glass window?

Yes; because the glass is transparent, and the light passes through it.

Can we see through a looking-glass?

No; because the back of the looking-glass is covered with quicksilver, which prevents the rays of light from passing through it.

What becomes of the light falling on the looking-glass?

It is thrown back from the glass.

What is this called?

It is called *reflection*.

What objects are good reflectors of light?

Those having smooth and polished surfaces; such as tin, silver, gold, and quicksilver.

27

What objects are poor reflectors of light?

Those having dull, uneven surfaces; such as iron, wood, cloth, leather, and calico.

Of what is every ray of sunlight composed?

It is composed of the seven colors of the rainbow.

What does a looking-glass do with these colors?

A looking-glass throws them all back from its surface.

What does a glass window do with these colors?

A glass window permits all these colors to pass through it.

What do opaque substances do with these colors?

They throw back or reflect some of them.

Do they all reflect the same color?

No; some reflect one color, and some another color.

What color does the grass reflect?

It reflects the green color; therefore, the grass is green.

What does the grass do with the other colors?

It absorbs or hides them in itself.

How do we know the color of anything?

We know it by the color which it reflects.

Why is the rose red?

Because it reflects the red color, and absorbs or hides the other colors in itself.

When anything *absorbs* all the colors of a ray of light, what color is it?

It is black.

When it *reflects* all the colors of light, what color is it?

It is white.

28

Why are the letters on this page black?

Because they absorb all the colors of light, and reflect none.

Why is the paper white?

Because it reflects all the colors of light, and absorbs none.

Why are all things black in the dark?

Because there are no rays of light falling on them; hence, there is no color for them to reflect.

Does an object reflect its color in every direction?

It does reflect its color in every direction.

How do we know this?

Because thousands of persons, in different directions from the same object, can see it at the same time.

How are the rays of color reflected from an object?

They are reflected in straight lines.

Where must a person be so as to see an object?

He must be in a position so that there is nothing to prevent the rays of light passing in a straight line from the object to his eyes.

What color does a red ribbon reflect?

It reflects a red color.

Why are some red ribbons of a brighter red than others?

When they reflect a great many red rays, they are of a bright red color; but when they reflect only a few red rays, they are of a dull red color.

Upon what does the brightness or dullness of a color depend?

It depends upon the number of rays of that color reflected.

29

What variety does this produce?

It produces a great variety in the shades and tints of color.

Where may many of these shades and tints be seen?

In the pretty flowers that grow in the woods, fields, and gardens; in the beautiful tints of the leaves in autumn; and in the plumage of the birds that visit us every spring, and cheer us with their songs.

What may these things teach us?

They may teach us the goodness of God, in giving us a world so full of beauty; and we should feel ever thankful to Him for the great pleasure that we have in seeing them.

Why cannot we see the light of a lamp or candle distinctly, in the day-time?

Because the strong rays from the sun hide the more feeble rays from the lamp.

Why cannot we see the stars in the day-time?

Because the bright light from the sun hides their more feeble light.

When can we see the glow-worms or fire-flies best?

At night, when it is dark; because, at other times, the light of the sun hides their feeble light.

Where may we see them at night?

Flying about in all directions, looking like bits of fire moving in the air.

Does a looking-glass reflect all the colors of light falling upon it?

It does; hence, the ray of light is not changed.

30

When the object is of a blue color, why is blue only reflected?

Because it is the only color falling upon the glass, and there is no other color to reflect.

Is the color of any object changed by falling upon a looking-glass?

No; the color of every object is reflected from a looking-glass without change.

Do other objects generally reflect the colors falling upon them?

They do not; they absorb or hide the color of all other objects, and reflect only their own color.

If every object was a good reflector of color, like a looking-glass, what would result?

Then every object would reflect the color of every other object around it, and there would be an endless confusion of colors.

What objects reflect the most light?

Those of a white or light color.

What objects reflect the least light?

Those of a darker color; and the nearer the color approaches to black, the less light it reflects.

Why is it darker when the sky is covered by dark-colored, than by light-colored, clouds?

Because the dark-colored clouds reflect less light, than the light-colored clouds do.

What advantage do we derive from the green color of the grass and the leaves?

They reflect a soft, pleasant light, which does not dazzle or hurt our eyes.

How would it be if those objects were white?

They would dazzle us by the amount of light reflected.

31

If we wish to make a room light, of what color should the walls be?

They should be white; and when papered, it should be with light-colored paper.

Why does dark-colored paper darken a room?

Because it absorbs some of the rays of light which come in at the windows; hence, there is less light in the room. Dark-colored carpets, or dark furniture, darken the room for the same reason.

Does the light from a burning body differ from sun-light?

Yes; it differs in intensity, in color, and in many other ways.

What effect does the lamp-light have upon the color of some substances?

It changes their color.

Where may we find an example of this?

In trying to match the colors of thread or silk at night.

Why is the color different by lamp-light from what it is by daylight?

Because the yellow color of the lamp's rays acts upon the color of the silk, forming a third color. Blue silk becomes green by lamp-light, and red silk becomes orange.

Are all persons able to distinguish one color from another?

No; some are color-blind. To such persons all colors appear to be alike.

What curious instances of color-blindness may be mentioned?

32

Dr. Mitchell tells of an officer who bought a blue coat and a red waistcoat, thinking them to be of the same color. He also tells of a tailor who patched a black waistcoat with a piece of crimson; and of another, who put a red collar on a blue coat. Dr. Dalton lost a piece of red sealing-wax in the grass, and he could not find it because it and the grass seemed of the same color to him.

Refraction of Light.

How do the rays of light from the sun come to us?

They come to us in straight lines.

When the rays of light pass from one substance to another more dense, what takes place?

They are bent or turned from a straight course.

What is said of these bent rays?

They are said to be *refracted*.

What is meant by refraction?

Bending a ray of light, as it passes from one substance to another of different density; as from air to water, or from water to air.

Where may we see an example of refraction?

In the rays of light from a rod which has one end in the water.



Fig. 7.

Why does the rod appear to be bent?

Because light coming from the part of the rod under the water, is refracted or bent at the surface of the water, while the light from the part above the surface, comes in straight lines to the eye; hence, the rod appears to be bent at the surface, as is represented in [Fig. 7](#).

33

How does a pole appear when one end is placed in the water?

It appears to be bent where it meets the surface of the water.

How does the part of the rod under water appear?

The part under the water appears to be raised up, as may be seen in [Fig. 7](#).

How does the bottom of a pond or stream of water appear?

It appears to be raised up, and the water does not seem so deep as it really is.

Why is this the case?

Because the light from the bottom of the pond is refracted or bent at the surface of the water; hence, the bottom appears to be raised

up.

How much does the bottom of a pond or stream of water seem to be raised up?
About one-third of the depth of the water.

If the water is really six feet deep, how deep does it appear?
It appears to be only four feet deep.

What has frequently happened from not knowing this fact?
People have been drowned from getting into water deeper than it appeared to be.

Do the fish and other things floating in the water appear to be raised up?
Yes; like the bottom of the stream, they also appear to be only two-thirds as far from the surface as they really are.

If we wish to spear the fish, what must we do?
We must aim below the place where they seem to be, or we must strike perpendicularly at them.

34

Reflection of Light.

When a ball is thrown against a wall, what is the path through which it goes called?
The line of incidence.

When the ball bounds back, what is its path called?
The line of reflection.

What is the angle at which a ball strikes the wall called?
The angle of incidence.

What is the angle at which the ball rebounds called?
The angle of reflection.

When a ray of light falls upon a looking-glass, what is the path through which it goes called?
The line of incidence.

When the ray is reflected, what is its path called?
The line of reflection.

The *angle of incidence* is the angle between a perpendicular and the line of incidence; and the *angle of reflection* is the angle between the perpendicular and the line of reflection. The two angles are always equal to each other, as is represented in [Fig. 8.](#)

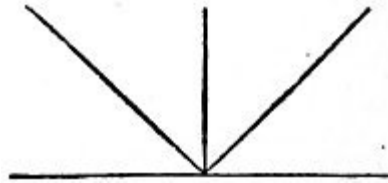


Fig. 8.

When a ray of light strikes a looking-glass obliquely or slantingly, what is done with it?

The ray is reflected as obliquely from the glass as it strikes or falls upon it.

Why is the reflection of the sun in a pond of water seen near the edge at noon?

35

Because the angle of reflection is equal to the angle of incidence; and the observer must be nearly over the place where the rays strike, so that, when reflected, they may meet his eye.

Where is the reflection seen in the morning or in the evening?

It is seen nearer the middle of the pond; because the sun's rays then fell more obliquely on the pond, and are reflected more obliquely to the eye.

When an opaque object is placed between a candle and a wall, why will there be a shadow?

Because the opaque object prevents the rays of light from falling on the wall.

Why will the shadow be larger, the nearer the object is to the candle?

Because the rays of light diverge, in every direction from the candle, in straight lines, and the nearer the object, the more rays will it intercept, as is represented in [Fig. 9](#).

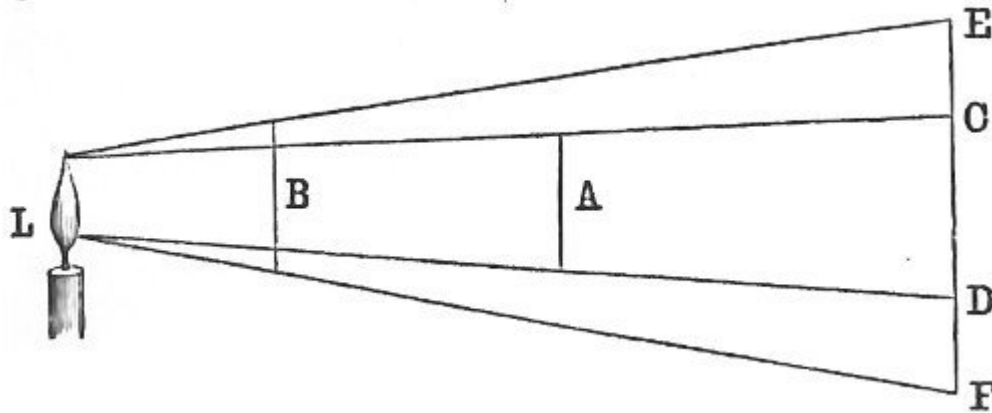


Fig. 9.

In [Fig. 9](#), let L represent the flame of a candle. When the object is placed at A, the shadow on the wall will extend from C to D; but when the object is moved nearer, as at B, the shadow will extend from E to F.

Why does an object seem to be smaller, the farther it is from us?

36

Because the angle at which the light from it strikes the eye, is less when at a distance, than when near to the eye.

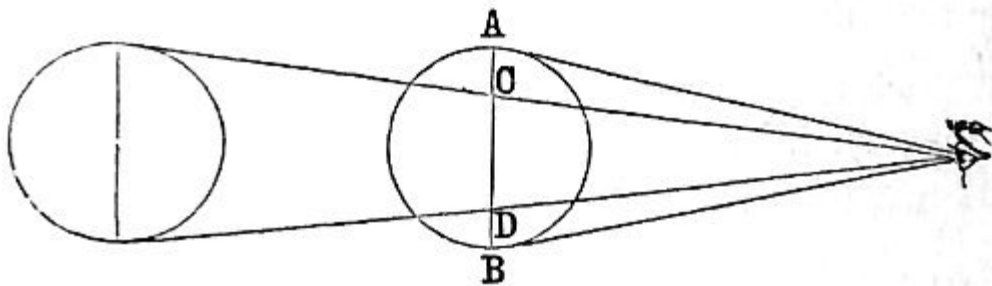


Fig. 10.

In [Fig. 10](#), the diameter of the near circle is from A to B; but the diameter of the more distant circle, although just as large, seems only to be from C to D.

Why does an object grow more dim the farther it is from us?

Because the rays of light from it spread out in every direction; and fewer rays enter the eye when it is at a distance than when it is near by.

What is the use of the telescope?

It is used to view distant objects.

Why can we see a distant object more distinctly with a telescope, than without one?

Because the telescope enlarges the image of the object, and it also collects more light from that object than is collected by the unaided eye; thus, making the image distinctly visible.

What class of objects do we view with a telescope?

We view the heavenly bodies; the sun, moon, and stars.

What is a spy-glass?

It is a glass mostly used to view distant objects on the earth.

37

Is the spy-glass like the telescope?

The spy-glass is much like the telescope, only it is smaller.

When looking through a spy-glass, how do objects appear?

They seem to be brought nearer to us, and they appear larger.

By whom are spy-glasses much used?

Spy-glasses are much used by persons on board of vessels, while at sea.

What instruments have we for magnifying small objects?

We have magnifying glasses and microscopes.

What are magnifying glasses?

They are single glasses or lenses, used for magnifying small objects.

By whom are magnifying glasses used?

They are used by jewellers, watchmakers, engravers, and others who examine small objects.

What are microscopes?

They are instruments used for examining very small objects.

How does a drop of rain-water or vinegar appear under the microscope?

It appears to be full of strange-looking creatures, which are always in motion.

How do the smallest insects appear?

They appear to be as perfectly formed as the larger ones which are seen with the naked eye.

What may be seen with a microscope?

Thousands of things too small to be seen by us unless they are magnified.

38

What kind of spectacles do near-sighted people use?

Near-sighted people use glasses, thickest at the edge and thinnest at the centre.

What kind of spectacles do we use as we grow old?

As we grow old we use glasses, thinnest at the edge and thickest at the centre.

Of what use are spectacles?

When the vision is defective, spectacles enable us to see objects more clearly.

How should spectacles be made?

They should be so made as to render objects distinct, but neither to magnify nor diminish them.

As people grow old, how do their eyes change?

Their eyes change so that they see objects at a distance better than those which are nearer, hence, in reading they hold a book farther from the eye.

The Eye.

What is that part of the eye called, which is blue, gray, or brown, in different persons?

It is called the *iris*.

What is the pupil of the eye?

The pupil is the black spot or hole in the centre of the iris.



Fig. 11.

What is the use of the pupil?

The pupil is the window of the eye, and the rays of light which enter the eye must pass through it.

What power has the iris over the pupil?

The iris has the power of making the pupil larger or smaller, according to the amount of light which it receives.

39

How does a bright light affect the iris?

It causes the iris to contract, so that the pupil becomes smaller.

How does a faint light affect the iris?

It causes the iris to dilate, so that the pupil becomes larger.

Of what advantage is the iris to the eye?

The iris acts like a sentinel to protect the eye from any sudden light.

How does a sudden light affect the eye?

A sudden light causes pain to the eye.

Of what shape is the pupil of the eye?

In man, the pupil of the eye is circular.

What is the size of the pupil of the eye?

The pupil varies from the one-twentieth to the one-third of an inch in diameter, depending upon the brightness of the light entering the eye.

How else are our eyes protected from any sudden light?

By means of our eyelids, which may be closed, and thus shut out all the light.

When we pass from a well-lighted room into the open air, at night, why does it seem darker at first than it does afterwards?

Because the pupil is contracted at first; but it soon dilates, and allows more rays of light to pass into the eye, so that the night seems less dark.

Why does the pupil become larger in the twilight?

So that more rays of light may enter the eye, whereby objects may be more distinctly seen.

40

Why can an owl or a bat see at night?

Because the pupil of the eye in them is quite large, and admits much light.

Why do they stay in dark places through the day?

Because the bright light of day hurts their eyes.

May the image of an object be retained in the eye after the eyelids are closed?

It may for a very short time, as any one can prove by first looking at some bright object, and then closing the eyelids.

Why does a burning coal moved rapidly around, seem like a circle of fire?

Because the light from it is retained a short time by the eye, thus seeming to form a complete circle.

Why cannot we count the posts in a fence, when riding rapidly in a car?

Because the light from each post falls in such quick succession upon the eye, that it cannot distinguish one post from another.

Can objects be seen distinctly when placed near the eye?

No; when objects are within six inches of the eye they cannot be seen distinctly.

Can objects be seen when at a great distance from the eye?

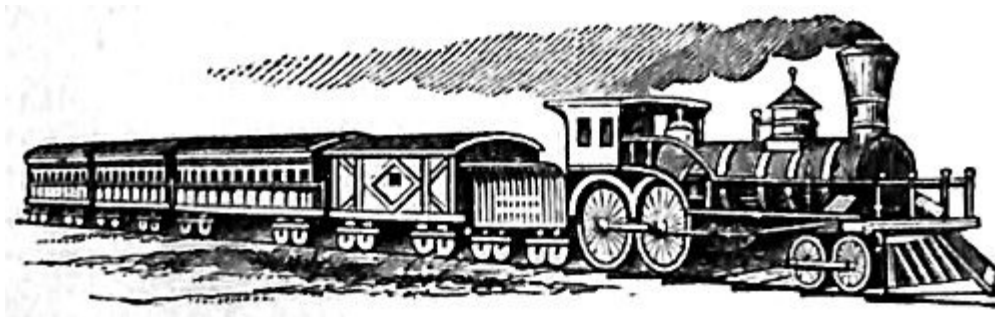
Yes; objects may be seen even when millions of miles away from us; thus, the sun is seen although ninety-five millions of miles from the earth, and some of the stars which we behold in the heavens, are still farther away than the sun. 41

Of what use is the eye to us?

The eye gives us ideas of the size, the shape, the color, the place, the distance, and the movements of things around us, so that we can use them the better to promote our comfort and our happiness.

What may we remember about the light?

And God said, "Let there be light;" and there was light. Thus the day was separated from the night, and the sun was made to send forth his silvery rays upon hill and valley, field and forest, causing the rarest buds and most beautiful blossoms to come forth from the lifeless earth, although no eye, save the All-Seeing One, was there to behold them!

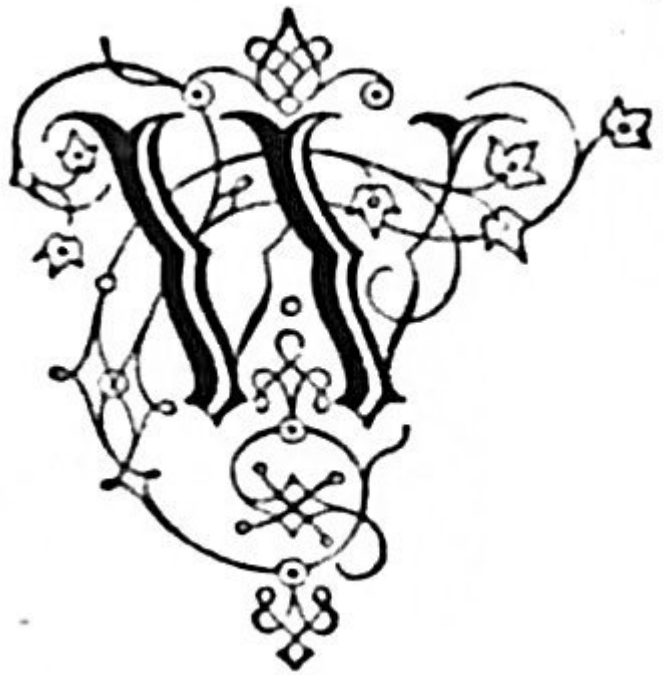




CHAPTER III.

HEAT.

SOURCES OF HEAT.



What is heat?

Heat is that agent which causes the feeling of warmth.

Can heat be seen?

No; heat cannot be seen, it can only be felt.

When we touch a substance hotter than we are, what takes place?

A part of the heat from that substance comes to us and causes a feeling of warmth.

When we touch a substance colder than we are, what takes place?

A part of the heat from us goes to that substance, and we experience a feeling of cold.

Does the amount of heat in any substance vary?

Yes; water may be heated until it is scalding hot, or the heat may be taken from it until it is frozen into ice.

What causes a substance to become cold?

Taking away heat from a substance causes it to become cold.

Then what is cold?

Cold is only the absence or want of heat.

43

When we pass from a very hot room to one moderately warm, how do we feel?

We experience a feeling of cold.

When we pass from a very cold room to one moderately warm, how do we feel?

We have a feeling of warmth, although the room is no warmer than in the first instance.

How else can we prove that we judge of heat and cold by our feelings?

If one hand be held in quite warm water, and the other in quite cold water, for a few moments, and then both hands be plunged into tepid water, the tepid water will feel cold to the hand that was in the warm water, and warm to the hand that was in the cold water.

Is there anything without heat?

No; the coldest substance known still contains some heat.

How many kinds of heat are there?

There are two kinds of heat.

What are the two kinds of heat?

Heat accompanied by light, as the heat from the sun, or a lamp; and heat without light, as the heat from boiling water.

From what source does heat mostly come?

Heat mostly comes from the sun, which is also the source of light.

What is said of the heat and light from the sun?

Heat and light from the sun come together in the sunbeam.

44

From what other source is heat obtained?

Heat is obtained from the burning of any substance.

What else does the burning of any substance produce?

It often produces light.

Can the light and heat from the sun easily be separated?

They cannot easily be separated.

What does a glass window do with the light and heat of the sunbeam?

It permits both the light and the heat to pass into the room, so that we can see the one and feel the other.

Are the light and heat from a fire united, as they are in the sunbeam?

They are not; but they seem to be separated from each other.

What does a glass window do with the light and heat from a fire?

It permits the light to pass through; but it stops the heat.

How may this be proved?

When a pane of glass is held between the face and a fire, it will protect the face from the heat.

Is there any heat without light?

Yes; many substances contain heat, but do not emit light.

Does light change the amount of heat in a substance?

No; boiling water is as hot in the dark as it is in the light; and ice is as cold in the daytime as it is at night.

Is there any other source of heat?

Yes; heat is produced by rubbing or striking substances together.

45

What will result from rubbing two pieces of wood together?
They may be rubbed until they take fire.

How do Indians kindle fires?
By rubbing two pieces of wood together until they take fire.

How is heat produced by the brakes on railroad cars?
It is produced by the car-wheels rubbing against the brakes.

What may be seen when a horse strikes his shoes against a stone?
Small sparks of fire, which contain heat, may be seen.

If a piece of iron be hammered, will its heat be increased?
Its heat will be increased.

How can this be proved?
A person can, by hammering a piece of cold iron, make it red-hot.

Could we live without heat?
No; our bodies must be kept warm, and this can be done only by heat.

Is this true of other living things?
Yes; all the animals and all the plants would die if heat were taken away.

How should we feel in regard to these things?
We should feel thankful to an All-wise Creator, for having provided us with both heat and light from a never-failing source—the sun.

Expansion by Heat.

How does heat generally affect substances?
Heat *expands* them or makes them larger.

Does heat expand all metals?
Yes; all metals are expanded by heat.

When a rod of iron is heated, is it longer or shorter than when cold?
It is longer than when it is cold.

How do we know this?

We know it by measuring the rod when it is cold, and again when it is heated.

Will the rod be larger, as well as longer?

The rod will be larger.

How can we prove this?

The rod, when red-hot, will not go through as small a hole as when it is cold.

How do heat and cold affect most substances?

Heat expands most substances, and cold contracts them.

Do all metals expand alike by heat?

No; some metals expand much more than others.

How does heat expand substances?

Heat pushes the parts or atoms of an object farther from each other, and thus its size is increased.

What does a blacksmith do with a tire before putting it on a wheel?

He heats the tire red-hot.

Why does he heat the tire red-hot?

So that it will be increased in size, and will go on the wheel more easily.

What takes place as the tire cools?

It becomes smaller, and thus binds the parts of the wheel tightly together.

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When a fire is made in a room, why does the furniture often make a snapping noise?

Because heat expands the wood, and the particles make a snapping noise upon separating.

Why does a stove make a crackling noise as it grows hot?
The particles of the iron make the noise in expanding.

If a piece of glass be held in the hand, will the glass become warm?
The glass will become as warm as the hand.

What part of the glass will be warmed first?
The part touching the hand will be warmed first.

What part of the glass will be warmed last?
The part farthest from the hand will be warmed last.

Which part of the glass will be expanded first?
The part touching the hand, because it is first warmed.

Which part will be expanded last?
The part farthest from the hand, because it is the last part warmed.

If any other warm substance touch the glass, will the glass be heated in the same manner?
The glass will be heated in the same manner.

What often results from this unequal heating?
The glass is broken.

Why are glass plates or tumblers broken when placed in hot water?
They are broken because the part next to the hot water is expanded more than that farther away.

48

Why will a cloth dipped in hot water and wrapped around the neck of a bottle loosen its stopper?

Because the heat from the cloth expands the neck of the bottle before it does the stopper, so that the stopper is loosened.

Why do stove-plates often break?
Because they are fitted together in the stove so that they have not room to expand without breaking.

What effect has cold upon substances?

Cold causes them to contract or grow smaller.

Things *expand* unequally; do they also *contract* unequally?

They do contract unequally, and in this way may be broken.

Why are lamp chimneys often broken while the lamp is burning?

Because the heat of the flame causes them to expand unequally.

In what other way are they broken?

By a draught of cold air, or a drop of cold water, touching them, thus causing them to contract unequally.

Why are they sometimes broken when the lamp is not burning?

Because a current of cold air from a window or a door, blows upon them.

Does quicksilver expand when heated?

Like other metals, quicksilver expands as it grows warmer, and contracts as it grows cooler.

Is quicksilver in the form of a solid or a fluid?

It is a fluid as we usually see it.

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For what is quicksilver used?

It is used for filling the tubes of thermometers.

What is a Thermometer?

It is an instrument used for measuring the degree or quantity of heat in any substance.

How does heat affect the quicksilver?

Heat expands the quicksilver, and causes it to rise in the tube.

How does cold affect the quicksilver?

Cold contracts the quicksilver, and causes it to fall in the tube.

Does heat expand liquids more than solids?

Heat does expand liquids more than solids.

Why are liquids expanded more than solids?

Because the particles of which they are formed are more easily separated or pushed apart by the heat.

If we continue to apply heat to a liquid, what becomes of it?

The liquid is changed into a gas or vapor.

What common example have we of vapor?

Water, when heated, is turned into steam.

Mention some gas.

The *air* we breathe is a gas.

How does heat affect the air?

Heat warms the air and causes it to expand.

Do solids all expand equally when heated?

No; some solids expand more than others; thus, zinc expands more than iron, and iron more than glass.

Do liquids all expand equally when heated?

No; liquids, although more sensitive to heat, do not expand as equally as solids.

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Do gases expand equally when heated?

Yes; gases expand uniformly; thus, 491 cubic inches of any gas, if heated one degree, will become 492 cubic inches.

If one cup be filled with lead, and another cup of the same size with water, which will weigh the more, the lead or the water?

The lead will weigh more than the water.

Which is the heavier substance, lead or water?

Lead is heavier than water.

Why do we say lead is heavier than water?

Because a cup full of lead will weigh more than the same cup full of water, or any bulk of lead will weigh more than an equal bulk of water.

Why is cork lighter than water?

Because any bulk of cork is lighter than an equal bulk of water; a cup filled with cork will weigh less than when it is filled with water.

When lead is put in water, why does it sink to the bottom?

Because the lead is heavier than an equal bulk of water.

When cork is put in water, why does it rise to the surface?

Because the cork is lighter than an equal bulk of water.

Does heat increase the weight of any substance?

Heat does not increase the weight of any substance.

How do we know this?

Because a piece of iron when cold will weigh as much as when heated red-hot.

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When a liquid is heated, does it become lighter or heavier?

It becomes lighter, bulk for bulk, when heated.

Why does a liquid become lighter when heated?

Because the same liquid is expanded and takes up more room, although it has no more weight.

Why will a gallon of cold water weigh more than a gallon of hot water?

Because a gallon of cold water, when heated, will make more than a gallon of hot water.

When do we get the most molasses, by buying it in hot or in cold weather?

We get the most by buying it in cold weather, because a gallon bought then will make more than a gallon when the weather becomes warmer.

Does heat expand the air and make it lighter?

Heat does expand the air and make it lighter.

What does the air do when heated?

It ascends or rises up, because it is lighter, and the cold or heavier air falls to take its place.

What part of a room, in which there is fire, is the warmest?

The part next to the ceiling is the warmest, because the heated air always ascends.

Why does a soap-bubble ascend?

Because it is filled with heated air from the lungs, and is, therefore, lighter than the air around it.

Why do balloons ascend?

Because they are filled with a gas lighter than the air around them.

Why does a chestnut split open when roasting?

Because the air in it is expanded by the heat, so that it bursts the shell.

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Why does the chestnut not split open when a hole is made in the shell?

Because the air can then escape as it expands, without bursting the shell.

What becomes of the air in an apple, when the apple is roasted?

The air, upon being heated, bursts through the peel of the apple, carrying the juice with it.

Why does an apple become soft when roasted?

Because the air in the cells of the apple expands, and breaks those cells, so that the apple becomes soft.

What part of the apple first becomes soft?

The outside, because it is first heated.

Why do all fruits and vegetables become soft when cooked?

Because the heat expands the air in them, and thus breaks up their cells, so that they become soft.

Why does wood make a snapping noise when burning?

Because the air in the cells of the wood bursts them apart, thus making the noise.

Why are sparks of fire thrown out?

Because the heated air bursts the cells with such force as to throw off small pieces of the burning wood.

What kinds of wood snap the most?

The coarse-grained kinds, like chestnut; while the finer-grained kinds, like walnut, seldom snap much.

Why does dry wood snap more than green wood?

Because the sap in the pores of the green wood dries up as the wood becomes dry, and its place is filled with air, so that there is more air in dry wood than in green wood.

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Why does smoke rise in a chimney?

Because the air in the chimney is heated by the fire, and as the air rises, it carries the smoke with it.

Why does a chimney smoke when the fire is first kindled?

Because the cold walls of the chimney cool the heated air so rapidly as to prevent its rising to the top, and the smoke then sinks back into the room.

How are houses heated with hot air?

By having the fires made in the cellar, so that the air when heated, may ascend through pipes to the different parts of the building.

Is there any substance that does not contract by cold?

Yes; water, when near freezing, does not contract by cold.

What takes place with the water?

When it is reduced nearly to the freezing point, it begins to expand, and when it freezes, it expands still more.

How much does water expand by freezing?

It expands about one-seventh of its bulk. That is, *seven* gallons of *water* will make *eight* gallons of *ice*.

Does freezing water expand with much force?

Yes; it expands with great force.

Why are vessels containing water often broken during a cold night?

As the water in them freezes, it expands and breaks the vessels.

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Why do lead pipes and iron pipes often burst during the winter?

Because the water in them is permitted to freeze, and as there is not room for it to expand, the pipes are burst.

Is ice heavier or lighter than water?

Ice is lighter than the same bulk of water.

How much lighter is ice than water?

Eight gallons of ice weigh no more than seven gallons of water.

Does the ice protect the water beneath it from freezing?

Ice does protect the water from freezing, to a very great extent.

If ice were heavier than water, what would result?

The ice would sink as rapidly as formed, and our streams would, every winter, freeze to the bottom, thus destroying the fish and other creatures living in them. In this, as in many other ways, we may learn the lesson, that in the creation of the world, God wisely made all things to serve some useful purpose.

Conduction of Heat.

Why does iron feel cold to the touch on a cold morning?

Because heat goes from the hand to the iron, thus giving the sensation of cold.

What is the passage of heat from the hand to the iron called?

It is called *conduction*.

When one end of a rod of iron is placed in a fire, does the whole rod become heated?

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The whole rod does become heated.

How does this take place?

The heat of the fire passes from one particle to another throughout the rod.

What is this called?

It is called *conduction*.

What then is conduction of heat?

It is the passage of heat from one body to another which it touches, or from one particle of a body to another particle of the same body.

What bodies are good conductors of heat?

Such bodies as gold, platinum, copper, silver, iron, zinc, tin, and lead, in the order named, are the best conductors of heat.

What bodies are poor conductors of heat?

Such bodies as glass, wood, charcoal, wool, hair, and fur.

Fur is the poorest conductor of heat known.

Why does a piece of wood blazing at one end not feel hot at the other end?

Because wood is a poor conductor, and the heat goes slowly through it.

Why does a piece of iron feel cold in winter?

Because the iron is a good conductor, and carries the heat away from our hands very rapidly.

Why does fur feel warmer than iron in the winter?

Because the fur is a poor conductor, and carries the heat away from our hands very slowly.

Why does a wooden pump-handle seem less cold than one of iron?

Because wood is not so good a conductor as iron; hence, it does not carry the heat of our hands away so rapidly.

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Why does carpet seem warmer than the bare floor?

Because the carpet is a poorer conductor than the wood of the floor, and does not carry away the heat of our bodies so rapidly.

Why does a stone pavement make our feet cold in winter?

Because the stone is a good conductor, and rapidly carries the heat away from our feet.

Why does heated iron feel hot to us?

Because the iron is a good conductor, and gives off its heat rapidly to our bodies.

Why does a piece of cloth, when heated, not feel hot?

Because the cloth is a poor conductor, and gives off its heat very slowly.

Why will a block of wood, when heated, remain hot longer than a heated brick?

Because wood is a poorer conductor than brick, and does not give off its heat so rapidly.

Why is a block of wood better than iron or brick, to keep our feet warm while on a journey?

Because it does not give off its heat so rapidly, and therefore remains warm longer than iron or brick.

Why should the wood or brick be wrapped in cloth?

Because the cloth, being a poor conductor, helps to keep the heat from passing off so rapidly.

Why does iron feel colder than water when both are at the same temperature?

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Because iron is a better conductor than water, and carries away the heat from our hands more rapidly.

Are liquids good conductors of heat?

No; liquids are poor conductors of heat.

Is air a good conductor of heat?

No; air is a poor conductor of heat.

Are gases as good conductors as liquids?

No; gases are poorer conductors than liquids.

Why is water a better conductor than air?

Because the particles of water are closer together than the particles of air.

Why is iron a better conductor than water?

Because the particles of iron are closer together than the particles of water.

How do we know that water is a poor conductor of heat?

Because water may be made to boil at its surface without melting ice a short distance below the surface.

How do we know that air is a poor conductor of heat?

Because the air at the ceiling of a room may be made very warm without melting ice near the floor.

Why does a linen shirt feel cool?

Because linen is a good conductor, and there is but little air among its fibres.

Why is a cotton shirt warmer than one made of linen?

Because the cotton contains more air among its fibres, and air is a poor conductor of heat.

Why is a woollen shirt warmer than one made of cotton?

Because wool contains more air among its fibres, and is, therefore, a poorer conductor of heat.

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Why is fur warmer than wool?

Because there is more air among the hairs of the fur, and it is, therefore, a poorer conductor of heat.

What fur is the warmest?

Fur with very fine hairs, like that of the rabbit, because it contains the most air.

Why is fur warmer when the hair is next to our bodies?

Because the fur and the air in it both help to keep the heat of our bodies from passing off rapidly.

Is the earth a good conductor of heat?

No; the earth is a poor conductor of heat.

How do we know that the earth is a poor conductor of heat?

Because the heat of summer warms the earth only a few inches below the surface.

How is it with the earth in winter?

In this latitude, the frost of winter reaches only a few inches below the surface of the earth.

In all parts of the earth, except in the Frigid Zones, the heat of the summer takes away the frost and ice of the winter, and the earth is warmed so that plants may grow.

Why is spring-water generally cool, even in summer?

Because the springs are mostly so far below the surface of the earth, that they are not warmed by the sun's rays.

Why is snow a warm covering for the earth?

Because the air among the particles of snow prevents the heat of the earth from passing off rapidly.

Why does wrapping straw around a pump in winter, prevent the water in it from freezing?

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Because the stalks of straw are hollow, and the air in the stalks makes them poor conductors of heat.

Will straw, wrapped around shrubbery, prevent it from freezing?

It will; because it keeps the heat of the shrubbery from passing off into the air.

Why are rooms warmer from having double windows?

Because the air which is confined between the double windows, being a poor conductor, keeps the warmth of the room from escaping.

Why is the space between the double walls of ice-coolers filled with charcoal?

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